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Factsheet

HEAT PUMPS IN AGRICULTURAL USES

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Energy costs will continue to rise in the long-run as will the cost of heating and cooling. One method of reducing heating costs is by using a heat pump. Heat pumps have been in use since the 1930's. They were originally designed and used in the Southern United States to provide air conditioning through their long, hot summers, and some heating in the short, relatively mild winters.

Ontario has the opposite situation, namely high heating and small cooling loads. Manufacturers have been developing heat pumps suitable for our cooler climate.

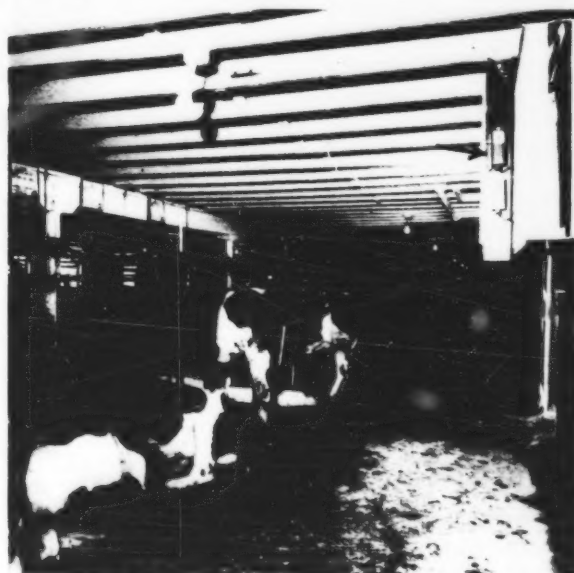


Figure 1 Heat pumps can recover heat from exhaust air from livestock and poultry barns. Note above the wall mounted heat pump which creates no loss of useable barn space.

WHAT IS A HEAT PUMP?

A heat pump upgrades heat from a low temperature to a higher temperature. The most common example of a heat pump is a home refrigerator where heat is "pumped" from the inside of the fridge and released from the coils on the back into the room.

Electrically powered heat pumps can normally recover and upgrade more units of heat than the same amount of electricity would produce in electric resistance heaters. Most of the heat comes from some external source although the heat produced by the motor and compressor

is recovered as well.

The type of heat pump is identified by the heat source and the heat sink, ie: where the heat is taken from and where the heat is released. The most common type is an air-to-air heat pump such as a refrigerator. Water-to-air heat pumps and liquid-to-liquid types are available as well.

A common type of heat pump on dairy farms is the milk cooler. Most of these are liquid-to-air, where the heat is 'pumped' from the milk and released to the air via the radiator-like coil and fan in the milkhouse. Liquid-to-liquid heat pumps may also be used where the milk heat is extracted and used to heat water. Further information on the latter is available in the OMAF Factsheet *Heat Recovery From Milk Cooling Systems*, Order # 82-065.

A good method for evaluating a heat pump's efficiency is the Coefficient of Performance, or COP. COP is defined as the energy produced (heat output) divided by the electricity consumption (input). The COP can go as high as 4, with typical values of 2 or more for average operation. Most air source heat pumps have a COP of 1 at -20°C or cooler.

$$\text{COP} = \frac{\text{OUTPUT (kW)}}{\text{INPUT (kW)}} = \frac{\text{(heat produced)}}{\text{(electricity consumed by the unit)}}$$

kW = Kilowatt

A feature that increases the COP and reliability of a heat pump is a 'Demand' defrost cycle that is initiated only if it is required.

Be sure to understand how much heat will be supplied by the heat pump and by the supplemental heat system. Most contractors will size a heat pump for home use based on the cooling load. Since the cooling load is less than the heating load in Ontario conditions, the heat pump will be undersized for heating and will make supplemental heating a necessity.

The compressor and controls should be located indoors, to avoid the need for crankcase heating, to reduce maintenance requirements, to increase reliability and to allow the compressor and refrigerant plumbing to contribute to the useful heat output in the winter months (See Figure 2).

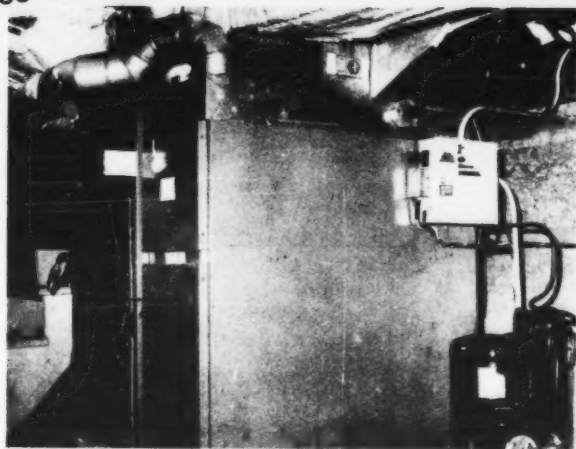


Figure 2 Heat pump systems can be easily integrated into existing furnaces. Note the compressor in the lower right corner.

HEAT PUMP APPLICATIONS

A heat pump's ability to remove heat from a variety of sources and boost this heat to a useable temperature means there are many potential applications on the farm. Typical applications include the following:

Air Source Heat Pumps - use outside air. Operating COP's range from 1.0 to 3.5, depending on outside temperature and efficiency of the heat pump. These units are commercially available, usually through a local heating contractor. They are quiet, reliable and can provide air conditioning for summer operation. A supplemental heat source is normally required for colder winter days, when the heat pump's COP is less than 1 and/or it cannot supply enough heat. Unfortunately, as outside temperatures fall, the amount of heat that air-source heat pumps can supply decreases while the heat required increases. This is a major shortcoming of the air-source heat pump for heating homes.

Further development work is being carried out by Ontario Hydro and heat pump manufacturers to improve efficiency. Because most heat pump designs are from the southern United States, the compressor and motor are usually located on a pad with the outdoor evaporator coil and the heat they produce is not recovered. Up to a third of the total potential heat of the heat pump can be lost to the outdoors because of this.

Waste-Heat Air Source Heat Pumps - can overcome the decrease in COP that air source heat pumps experience. For example, the temperature of the exhaust air from livestock barns remains relatively high throughout the winter. An evaporator or 'outdoor' coil placed in front of the minimum winter ventilation fan will recover energy from the warm exhaust air.

The recovered heat may be used to heat water or provide space heating or both in the home or barn. If there are sufficient quantities of heat recovered from the warm barn exhaust air, it may not be necessary to add supplemental heat.

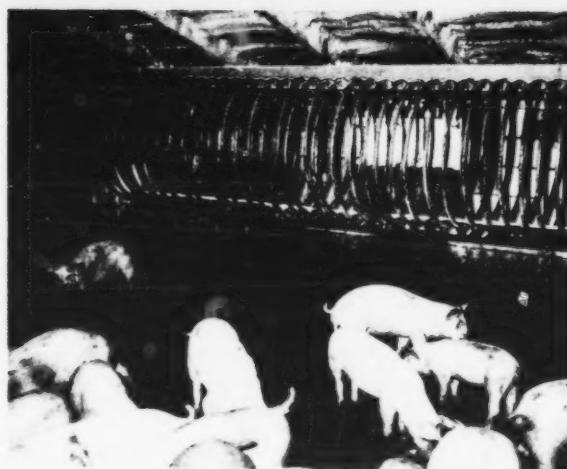


Figure 3 Water circulated through the plastic tubing picks up heat from air in the finishing hog barn. This warmed water is then pumped to the farm home where a heat pump extracts the heat for home heating.

Recovery of exhaust air heat has now been used on several farms in Ontario. Two dairy farmers and one hog farmer (Figure 3) heat their farm homes almost entirely using the exhaust air from their livestock barns. Another hog farmer heated his farrowing and weaning rooms using recovered exhaust heat from the finishing hog barn. In this case, a commercial air-source heat pump was installed. Reliability problems ensued due to the contaminated air corroding solder joints. Eventually, leaks formed and the project was abandoned. Corrosion is avoided by using plastic piping as the heat exchange surface, as opposed to aluminum finned-copper tubing refrigerant coils. Caution is required where any heat pump components are exposed to barn air that has a corrosive nature (i.e. hogs, poultry, etc.).

Water Source Heat Pump - use ground water from wells or artesian wells. These are particularly well suited because of higher temperatures even in the winter (7 C° or higher is normal). The heat pump will cool the water 2 to 4 C°. Nearby streams, lakes and ponds may not be able to provide enough heat because of the low temperatures that they reach in the winter. Further cooling of this water can cause the evaporator coil to freeze up.

High COP's are achieved from ground water sources. Up to 50-100 L/min (11-22 gpm) of water will be required for heating an average farm-house. This cooled water must be disposed of so that it does not cause drainage problems, nor get back into the well that is being used as the water source. One hog producer heats his home, then pumps the cooled water to a drinking water storage tank for his hogs.

A vegetable grower is heating 7000 m² of greenhouse by pumping up to 170 L/min of water through water source heat pumps (see OMAF Factsheet *Water Source Heat Pumps*, Order No.82-090).

If discharge water flows exceed 45,000 L/day, be sure to check with your township about by-laws that may limit the amount of water you may use. Also, water flows at the above rate requires a permit from the Ontario

Ministry of the Environment
(Phone: 416-965-6995).

Ground Source Heat Pumps - extract heat from the earth. In most parts of Southern Ontario, the frost line rarely reaches 1 m in depth. There is heating energy available below this frost line. The most common method of extracting this heat is to bury polyethylene tubing 1.5 to 3 m below the ground surface. The length of this tubing will depend upon the heat required, the depth it is buried and the ground temperature. A typical 140 m² (1500 ft²) home would require 600-750 m (2000-2500 ft) of buried tubing.

This polyethylene tubing is then filled with a brine or alcohol solution that will withstand below freezing temperatures. The brine is pumped around the tube network gathering heat from the ground. Heat is extracted from the brine using a heat pump and released into the home. The brine is once more sent around the loop to extract heat from the ground.

Throughout the summer the ground will be reheated by the sun. This reheating will occur even faster if the loop is used for air conditioning as heat extracted from the house is returned to the ground via the tubing.

OTHER HEAT SOURCES AND APPLICATION OF HEAT PUMP TECHNOLOGY

European research has found that heat can be extracted from manure. Plastic tubing (which will resist corrosion) can be located in a manure pit that is flushed on a regular basis. Heat can be removed, the manure pumped to storage and another batch brought in. However, too much heat removal from the manure will cause bacterial action to slow, which may cause the manure to freeze.

Many livestock facilities suffer from humidity problems in the winter months. Ventilation is required to remove this excess moisture, which also means that the fresh cold outside air may require heating, particularly for small animals. The Agricultural Energy Centre is examining the possibility of a small heat pump used as a dehumidifier. Lowering the moisture content of the air will allow a reduction in the amount of ventilation air required, reducing or eliminating the need for supplemental heat (See Figure 4).



Figure 4 Note the commercially available dehumidifier in the upper right corner of this veal room.

COSTS

Heat pumps vary widely in price, depending on the heat source. A summary below provides a basis for comparison of home heat pump systems.

Type & Size	Cost (Fall, '84)	Installation Costs	Comments
3-ton Air Source	\$3,000-4,000	included	-will require supplemental heat. May not operate at sub-freezing temperatures.
5-ton Waste Heat Source	\$6,000	included	-can provide all heating requirements.
3-ton Water Source	\$4,500-5,600	included	-can provide all heating requirements.
3-ton Ground Source	\$5,600	\$2,600 for ground loop	-can provide all heating requirements.

A 10 kW heating coil for supplemental heat will cost an additional \$500. The electrical service may also require upgrading, particularly if it is only a 100 Amp service.

CONCLUSIONS

A heat pump can be used to provide part or all of the heat required in many places on the farm. Heat sources such as livestock building exhaust air, groundwater or the earth provide a heat pump with a steady energy source, improving performance and reducing operating/maintenance costs.

Local heating/refrigeration contractors can assist you with your ideas and answer most questions.

Further information and assistance is available from your local OMAF office, Ontario Hydro, the Ontario Ministry of Energy, or the Department of Energy, Mines and Resources Canada.

GLOSSARY OF HEAT PUMP TERMS

Air source - Heat is removed from air, such as outside ambient or barn exhaust air.

Water source - Heat is removed from water, such as pumped well water, springs, etc.

C.O.P. (Coefficient of Performance) - An expression that compares energy input to output, usually in the electrical term of kW or kWh.

$$\text{COP} = \frac{\text{OUTPUT}}{\text{INPUT}}$$

Heat pump COP's range from 1.0 to 4.0.

Compressor - The component that does the actual work so that heat can be made to flow from a cold area to a warm one.

Condenser coil - The coil that releases heat to the air or water requiring heating.

Evaporator coil - The coil that removes heat from the heat source.

Ground source - Heat is removed from the ground via buried plastic tubing, located below the frost line.

Heat pump - A device similar in nature to a refrigerator that removes heat from one area and releases the heat at a higher temperature at another area.

Refrigerant - Typically a non-toxic, non-flammable liquid vapour used to transport the heat in the heat pump cycle.

Supplemental heat - Additional heat required to maintain a comfortable environment.